Amendments to the Claims

This listing of claims will replace all prior versions, and listings, of claims in the application:

Listing of Claims:

1. (Currently Amended) A computer-implemented method for training a fuzzy logic inference system to produce an output indicative of a characteristic of ~~a~~ an electrochemical system in response to a plurality of parameter values of the electrochemical system, the method comprising:
~~a)~~ providing a prototype set of fuzzy logic membership functions, the prototype set comprising a plurality of membership functions corresponding to each of ~~the~~ a plurality of input parameters wherein the membership functions each produce an output that is a function of a value of the corresponding input parameter;
~~b)~~ obtaining parameter values for the input parameters from a calibration system for which the characteristic has a known value;
~~c)~~ for each of the parameter values obtained from the calibration system obtaining a system-specific set of fuzzy logic membership functions by scaling the corresponding plurality of membership functions relative to parameter value axes of the membership functions; and,
~~d)~~ using the system-specific set of membership functions to obtain outputs indicative of the characteristic of electrochemical test systems.

2. (Original) The method of claim 1 wherein the system comprises an electrochemical battery and the characteristic comprises a state of health of the battery.

3. (Previously Presented) The method of claim 2 wherein providing the prototype set of fuzzy logic membership functions comprises determining a chemistry type of the battery and selecting from a plurality of prototype sets of fuzzy logic membership functions a prototype set of fuzzy logic membership functions which matches the chemistry type of the battery.

4. (Original) The method of claim 2 wherein the fuzzy logic membership functions are triangular membership functions completely specifiable by three numbers.

5. (Original) The method of claim 4 wherein each of the membership functions is specified by a left intercept point, a mid-point and a right intercept point.

6. (Previously Presented) The method of claim 5 comprising optimizing the system-specific set of membership functions by:

obtaining parameter values from one or more calibration batteries having known states of health,

computing a state of health based upon the parameter values using the system-specific set of membership functions,

comparing the computed state of health to the known state of health, and,

flexing one or more of the membership functions in the system-specific set of membership functions.

7. (Original) The method of claim 6 wherein optimizing the system-specific set of membership functions comprises simultaneously flexing two or more of the membership functions in the system-specific set of membership functions.

8. (Original) The method of claim 6, wherein flexing one or more of the membership functions comprises determining a state of health for the calibration battery that would be obtained if the membership function were flexed by each of a plurality of different amounts and flexing the membership function in an amount corresponding to the determined state of health which best matches the actual state of health of the calibration battery.

9. (Previously Presented) The method of claim 8 wherein determining a state of health for the calibration battery that would be obtained if the membership function were flexed by each of a plurality of different amounts and flexing the membership function comprises:
   a) providing a step size;
   b) adding a multiple of the step size to a point of a triangular membership function to be flexed;
   c) initializing a counter and a threshold value;
   d) subtracting the step size from the point;
   e) computing state-of-health of the calibration battery using the flexed triangular membership function;
   f) obtaining a difference between the computed state-of-health and the known state-of-health;
   g) if a magnitude of the difference is less than a threshold value, setting the threshold value equal to the magnitude of the difference;
   h) incrementing the counter; and
   i) repeating steps d) to h) until the counter reaches a predetermined maximum number of repetitions.

10. (Previously Presented) The method of claim 5 comprising optimizing the system-specific set of membership functions by:

obtaining parameter values from one or more calibration batteries having known states of health,

computing a state of health based upon the parameter values using the system-specific set of membership functions,

comparing the computed state of health to the known state of health, and,

translating one or more of the membership functions in the system-specific set of membership functions.

11. (Original) The method of claim 10, wherein translating one or more of the membership functions comprises determining a state of health for the calibration battery that would be obtained if the membership function were translated by each of a plurality of different amounts and translating the membership function in an amount corresponding to the determined state of health which best matches the actual state of health of the calibration battery.

12. (Previously Presented) The method of claim 11, wherein determining a state of health for the calibration battery that would be obtained if the membership function were translated by each of a plurality of different amounts and translating the membership function comprises:

a) providing a step size;
b) adding a multiple of the step size to the points that define the membership function;
c) initializing a counter and a threshold value;
d) subtracting the step from the points that define the triangular membership function;
e) modifying any points necessary to maintain all values of points positive;

f) computing state-of-health using the translated triangular membership function;

g) obtaining the difference between the computed state-of-health and the reliably-measured state-of-health;

h) storing the points and setting a new threshold value equal to the magnitude of the difference if the magnitude of the difference is less than the threshold value;

i) incrementing the counter; and

j) repeating steps d) to i) until the counter reaches a predetermined maximum number of repetitions.

13. (Original) The method of claim 6 comprising sequentially optimizing the membership functions associated with a plurality of the parameters.

14. (Previously Presented) The method of claim 10, wherein obtaining parameter values from the calibration battery comprises applying a test current waveform to the calibration battery; and computing a state of health based upon the parameter values using the system-specific set of membership functions comprises:

a) deriving antecedent membership values in a number of fuzzy logic sets according to the values of the measured parameters;

b) deriving consequent membership values by the application of fuzzy logic rules to the antecedent membership values; and,

c) deriving an assessment of state-of-health by computing a weighted average of the consequent membership values.

15. (Original) The method of claim 10 wherein a plurality of the parameters are selected from the group consisting of:

an internal resistance; an open circuit voltage; a voltage measured while the battery is under load; and a time taken for a voltage to achieve a specified value.

16. (Original) The method of claim 1 wherein the fuzzy logic membership functions are triangular membership functions each having a left intercept point, a mid-point and a right intercept point wherein the method comprises refining the system-specific set of membership functions by, for each of a plurality of calibration systems:
   a) determining a value for the characteristic and measuring a plurality of parameter values;
   b) based upon the value of the characteristic, assigning the calibration system to a calibration category;
   c) based upon the calibration category, identifying a particular point on one of the plurality of membership functions associated with each of the parameters to be scaled; and,
   d) for the plurality of membership functions associated with each of the parameters, scaling the point.

17. (Original) The method of claim 16 wherein scaling the point comprises taking a weighted average of a measured parameter value of the test system and a current value for the point.

18. (Previously Presented) The method of claim 17 wherein scaling the point comprises performing the computation:

$$x_{new} = \frac{c \times x_{old} + \left[(1-z)x_{old} + zy\right]}{c+1}$$

where x_{new} is the new value for the point, x_{old} is the existing value for the point, z is a function of the value of the characteristic for the calibration system, y is one parameter value of the calibration system, and c is a number of calibration systems that have previously been associated with the calibration category.

19. (Original) The method of claim 18 wherein z is given by:

$$z = \frac{B - Characteristic\,Value}{B - A}$$

where A and B are scaling values associated with the calibration category of the test system.

20. (Original) The method of claim 19 wherein the calibration categories correspond to the characteristic value of the calibration system as set out in Table IV.

21. (Original) The method of claim 1 wherein the fuzzy logic membership functions are triangular membership functions each having a left intercept point, a mid-point and a right intercept point and the method comprises optimizing the system-specific set of membership functions by:

obtaining parameter values from one or more additional calibration systems having known characteristics;

for each of the calibration systems computing a characteristic value based upon the parameter values using the system-specific set of membership functions;

comparing the computed characteristic to the known characteristic; and,

flexing one or more of the membership functions in the system-specific set of membership functions in

response to a difference between the computed characteristic and the known characteristic.

22. (Original) The method of claim 21 wherein optimizing the system-specific set of membership functions comprises simultaneously flexing two or more of the membership functions in the system-specific set of membership functions.

23. (Original) The method of claim 1 wherein the fuzzy logic membership functions are triangular membership functions each having a left intercept point, a mid-point and a right intercept point and the method comprises optimizing the system-specific set of membership functions by:

obtaining parameter values from one or more additional calibration systems having known characteristics;

for each of the calibration systems computing a characteristic value based upon the parameter values using the system-specific set of membership functions;

comparing the computed characteristic to the known characteristic; and,

translating one or more of the membership functions in the system-specific set of membership functions in response to a difference between the computed characteristic and the known characteristic.

24. (Currently Amended) An automatic battery testing method which comprises training a fuzzy logic battery analyzer for assessing the state-of-health of batteries of a known model and chemistry type, the method comprising:
~~a)~~ providing a prototype set of prototype fuzzy logic membership functions which matches the chemistry type of the model of batteries to be tested <u>wherein the</u>

membership functions each produce an output that is a function of a value of a corresponding parameter;

~~b)~~ measuring a capacity of a battery of the model of batteries to be tested which has a known state of health ~~,~~ and ~~c)~~ applying a current waveform to the battery and measuring a plurality of parameter values;

~~d)~~ for each of the parameter values obtaining a model-specific set of fuzzy logic membership functions by scaling a corresponding plurality of the membership functions ~~in~~ of the prototype set relative to parameter value axes of the membership functions; and,

~~e)~~ using the model-specific set of membership functions in combination with a set of fuzzy logic rules to assess the states of health of one or more batteries to be tested.

25. (Original) The method of claim 24 wherein each of the membership functions is defined by a plurality of points and, scaling a corresponding plurality of membership functions in the prototype set comprises, based upon the known state of health, for each parameter, identifying a point in a membership function corresponding to the parameter; and scaling all of the points for membership functions corresponding to the parameter by a scaling factor based upon the measured value of the parameter and the value of the identified point.

26. (Previously Presented) The method of claim 25 wherein the scaling factor is given by:

$$\alpha_0 = \frac{[(1-z)x + zy]}{x}$$

where z is a function of the value of the known state of health of the calibration battery, x is the value of the

identified point, and y is the parameter value measured for the calibration battery.

27. (Previously Presented) The method of claim 26 wherein z is given by:

$$z = \frac{B - SoH_{RM}}{B - A}$$

where A and B are scaling values associated with a calibration category of the test system and SoH_{RM} is the known state of health of the calibration battery.

28. (Original) The method of claim 27 wherein the calibration categories correspond to the characteristic value of the calibration system as set out in Table IV.

29. (Original) The method of claim 25 wherein the membership functions are triangular.

30. (Original) The method of claim 14, comprising assessing a state of health of a test battery by obtaining a set of measured parameter values for the test battery, from the measured parameter values computing membership in fuzzy sets specified by the membership functions in the model-specific set of membership functions and applying a set of fuzzy logic rules to the fuzzy sets.

31. (Original) The method of claim 30 wherein the fuzzy logic rules comprise a rule for each possible combination of memberships of the parameters.

32. (Original) The method of claim 31, wherein applying the set of rules comprises evaluating each rule by computing the minimum of the antecedent membership values considered by the rule.

33. (Original) The method of claim 32, wherein the fuzzy logic rules are grouped and each group of rules is associated with a definitional consequent membership value in a set of definitional consequent membership values.

34. (Original) The method of claim 33, wherein the set of definitional consequent membership values is ordered and equi-spaced throughout a desired range of output values.

35. (Original) The method of claim 34 comprising a state of health for the test battery as a centroid of weighted definitional consequent membership values.

36. (Cancelled)

37. (Currently Amended) A computer-implemented method for training a characteristic measuring system to produce an output indicative of a characteristic of ~~a~~ an electrochemical test system in response to a plurality of parameter values of the test system, the method comprising:

providing a prototype set of functions, the prototype set comprising a plurality of functions, each one of the functions corresponding to a corresponding one of the parameters wherein the functions each produce an output that is a function of a value of the corresponding one of the parameters;

obtaining parameter values for each of the parameters from a calibration system for which the characteristic has a known value;

for each of the parameter values obtained from the calibration system, obtaining a system-specific set of functions by scaling the corresponding plurality of

functions relative to parameter value axes of the functions; and

using the system-specific set of functions to obtain one or more outputs indicative of the characteristic of ~~a~~ an electrochemical test system.

38. (Previously Presented) A method according to claim 37 wherein the functions are triangular functions.

39. (Previously Presented) A method according to claim 38 wherein the triangular functions each have a left intercept point, a mid-point and a right intercept point and the method comprises:

obtaining parameter values from one or more additional calibration systems having known characteristics;

for each of the calibration systems, computing a characteristic value based upon the parameter values using the system-specific set of triangular functions;

comparing the computed characteristic to the known characteristic; and

moving one or more of the left intercept point, mid-point and right intercept point for one or more of the triangular functions in the system-specific set of triangular functions in response to a difference between the computed characteristic and the known characteristic.

40. (Previously Presented) A method according to claim 38 comprising:

obtaining parameter values from one or more additional calibration systems having known characteristics;

for each of the calibration systems, computing a characteristic value based upon the parameter values using the system-specific set of triangular functions;

comparing the computed characteristic to the known characteristic; and

translating one or more of the triangular functions in the system-specific set of triangular functions in response to a difference between the computed characteristic and the known characteristic.